Vacuum xxx (2016) 1–5

Contents lists available at ScienceDirect

Vacuum

journal homepage: www.elsevier.com/locate/vacuum

Trapping and desorption of hydrogen isotopes under irradiation of zirconium by deuterium atoms of thermal energies

A.E. Evsin [a, *], L.B. Begrambekov [a], A.I. Gumarov [b], A.S. Kaplevsky [a], A.G. Luchkin [b], L.R. Tagirov [b], I.R. Vakhitov [b]

[a] National Research Nuclear University "MEPhI", 115409, Kashirskoe sh. 31, Moscow, Russia
[b] Kazan Federal University, 420008, Kremlevskaya str. 18, Kazan, Russia

ARTICLE INFO

Article history:
Received 23 October 2015
Received in revised form
26 January 2016
Accepted 27 January 2016
Available online xxx

Keywords:
Zirconium
Hydrogen
Trapping
Desorption
Atomic irradiation
TDS
XPS

ABSTRACT

The results on trapping and desorption of hydrogen isotopes under irradiation of zirconium by deuterium atoms of thermal energies are presented. It is shown that the addition of oxygen to the operating gas during the irradiation causes the increase of the oxide layer thickness, the amount of hydroxyl groups in it and deuterium trapping in zirconium. Accelerated transport of deuterium atoms through the oxide layer saturated by hydroxyl groups is observed. Mechanisms of trapping and desorption of hydrogen isotopes and the role of oxygen in these processes are discussed.

1. Introduction

Hydrogen behavior in metals is a very important aspect in many applications. Therefore, this subject has been actively investigated for a long time. It is known that oxide layers on the surfaces of some metals (e.g. zirconium, titanium, yttrium, etc.) and their hydrides act as a surface barrier that mitigates both hydrogen penetration into the metal and hydrogen desorption from the metal or from the hydride [1–6]. Authors of Ref. [7] and our previous papers [8–11] demonstrated that irradiation of the oxidized metal surface by low-energy ions, or by thermal-energy atoms, alters barrier properties of the oxide and influences trapping and desorption of hydrogen isotopes. A full picture of the processes which determine hydrogen transport through the surface oxide layer and include the participation of atomic particles irradiation is still absent. This work is dedicated to the investigation of the mechanisms and regularities of trapping and desorption of hydrogen isotopes under irradiation of zirconium by deuterium atoms of thermal energies, and was carried out by means of thermal desorption spectroscopy (TDS) and X-ray photoelectron spectroscopy (XPS).

2. Experimental

The investigated samples were segments ~7 mm × 7 mm × 1 mm of tubes made of zirconium alloy E110 (Zr−1%Nb) preliminarily rinsed in the ultrasonic ethanol bath.

Irradiation of the samples by D-atoms of thermal energies was performed in "MIKMA" device that allows irradiation of a sample by atoms, ion beams, ions and electrons of a gas discharge, and then to transfer it to another chamber for TDS analysis without breaking vacuum [12]. Atomic flux onto the surface of the sample was produced by a device [13], where deuterium atoms were generated by means of heating of the tungsten spiral up to ≈1800 K in gaseous deuterium. The design of this device provides atomic flux directed perpendicular to the surface of the sample. Deuterium atoms emitted in other directions recombine into molecules by multiple collisions with the structural elements of the device.

Parameters of the experiments were as follows. The operating gas was the mixture $D_2 + (0–30)\%O_2$ with the deuterium pressure of 1.2×10^{-1} Pa measured by a vacuum capacitance manometer (Baratron). The atomic flux onto the surface was estimated as

* Corresponding author.
E-mail address: evsin@plasma.mephi.ru (A.E. Evsin).

http://dx.doi.org/10.1016/j.vacuum.2016.01.022
0042-207X/